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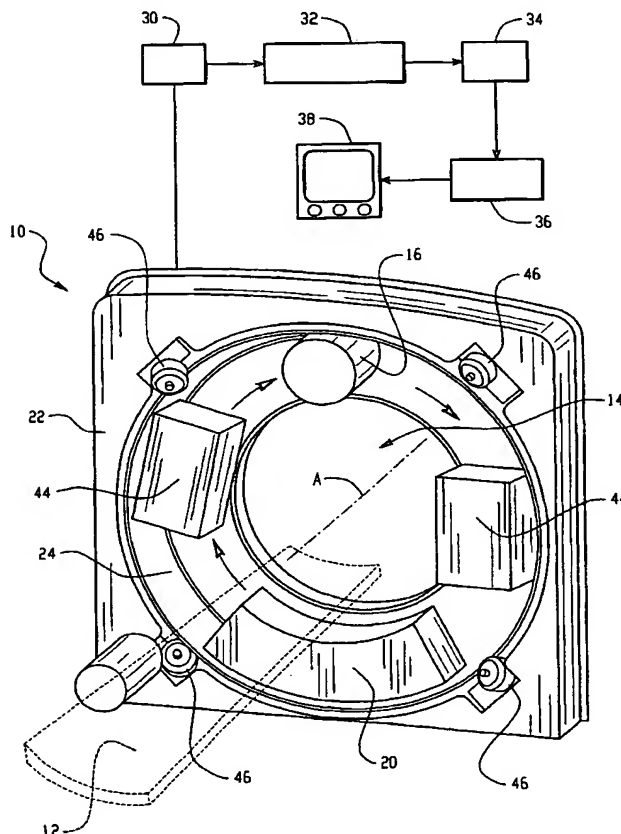
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- (71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).
- (71) Applicant (for AE only): U.S. PHILIPS CORPORATION [US/US]; 1251 Avenue of the Americas, New York, NY 10510-8001 (US).
- (72) Inventors: BRUNETT, William, C.; 595 Miner Road, Cleveland, OH 44143 (US). SHARPLESS, Ronald, B.; 595 Miner Road, Cleveland, OH 44143 (US).
- (74) Common Representative: KONINKLIJKE PHILIPS ELECTRONICS N.V.; c/o LUNDIN, Thomas, M., 595 Miner Road, Cleveland, OH 44143 (US).
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[Continued on next page]

(54) Title: TAPERED ROLLER BEARING



(57) Abstract: In a diagnostic system, having a rotating gantry (24) and a stationary gantry (22), a bearing race (50) rotates with surface portions having varying linear velocities in accordance with distance from an axis (A) of rotation. Tapered roller bearings (46) interface the bearing race (50) and are conically shaped to velocity match the variable linear surface velocity race (50). The race (50) preferably includes two faces, which provide both axial and radial supporting surfaces for the bearings (46) to interface. The bearings (46) are disposed about the race (50) in pairs. A drive motor (52) is connected to one of the bearings (46) to rotate the gantry (24).

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TAPERED ROLLER BEARING

The present invention relates to medical imaging arts. In particular, it relates to a rotating gantry such as those found in 3rd and 4th generation CT scanners, and will be described with particular reference thereto. However, the invention will also find application in conjunction with nuclear cameras and other imaging systems with rotating bearings, and is not limited to the aforementioned application.

Typically, 3rd and 4th generation CT systems have rotating gantries and stationary gantries. The two gantries are interfaced by a bearing system that allows rotation of the first gantry relative to the second gantry.

A large ball bearing assembly, often a meter or more in diameter, has been used to provide the interface between the gantries. Large ball bearing assemblies are expensive and tend to be noisy.

In other systems, roller bearings have been used. Cylindrical rollers support the rotating gantry in both axial and radial directions. Typically, the rotating gantry has three bearing races, or tracks along which the bearings roll. A circumferential race allows the bearings to give the rotating gantry radial support (a normal force counteracting the force of gravity) while the second and third races allow bearings to give the rotating gantry lateral, that is, axial support. To prevent the rotating gantry from wobbling, the roller bearings press against the second and third races with significant opposing pressure.

While the gantry rotates with a constant angular velocity, portions of the gantry move with different radially dependent linear velocities. More specifically, portions of the second and third races more distant from the rotational axis of the gantry have a higher linear velocity than portions closer to the rotational axis. Stated differently, the linear velocity of any moving element is a function of radial position, as well as angular velocity of the gantry.

This is significant to, among other things, the second and third axial support bearing races. The outer edges of these two races move faster than the inner edges of the same races. Each cylindrical roller bearing that contacts the second and third races only rotate at a single speed. Thus, slippage occurs between the bearing races and the roller bearings, causing high friction and wearing both the bearing races and the bearings prematurely. Additionally, functional speeds of the gantry are limited, in order to balance the speed of the gantry and the wear that higher speeds incur on the races and the bearings.

The present invention contemplates an improved apparatus and method, which overcomes the aforementioned limitations and others.

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According to one aspect of the present invention, a diagnostic imaging device is provided. First and second gantries are interfaced by a plurality of tapered roller bearings that provide support for the second gantry as it rotates. The bearings interface bearing races on the rotating gantry.

According to another aspect of the present invention, a method of diagnostic imaging is provided. A first, rotating gantry is supported with a plurality of tapered roller bearings attached to a second gantry. The first gantry is rotated concurrently with the roller bearings, races of the gantry being in contact with the roller bearings.

One advantage of the present invention resides in increased life of the roller bearings and bearing races.

Another advantage resides in a reduced total number of roller bearings required.

Another advantage is that rotating friction of the bearing system is reduced.

Another advantage is that a single size of roller bearing can be used.

Another advantage resides in fewer precision machined bearing races.

Another advantage resides in a smaller rotating gantry.

5 Another advantage resides in an integrated drive motor.

Another advantage resides in reduced cost over similar systems currently in production.

10 Yet another advantage resides in faster rotational speeds.

Numerous additional advantages and benefits of the present invention will become apparent to those of ordinary skill in the art upon reading the following detailed description of the preferred embodiment.

15

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for the purpose
20 of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of a computed tomography scanner, in accordance with the present invention;

25 FIGURE 2 is a cross-sectional view of the rotating gantry of FIGURE 1 and tapered roller bearings, in accordance with the present invention;

FIGURE 3 is a detailed view of the roller bearings of FIGURE 2 including a drive motor;

30 FIGURE 4 is a geometrical representation of a bearing-race interface, in accordance with the present invention;

FIGURE 5 is an alternate two-face race embodiment of the present invention;

35 FIGURE 6 is an alternate three-face race embodiment of the present invention.

With reference to FIGURE 1, a CT scanner 10 includes a subject couch 12 for moving a subject disposed thereon into and out of an imaging region 14. X-rays from an x-ray source 16 are shaped and collimated into a fan beam, pass through the imaging region 14 and are detected by a detector assembly 20 on the far side of the imaging region 14. In the illustrated 3rd generation embodiment, the source 16 rotates concurrently with the detector assembly 20, always remaining 180° around the imaging region 14 from the detector assembly 20 as it rotates around an axis A. Alternately, a stationary ring of individual detectors on the stationary gantry 22 can replace the detector array 20, as in a 4th generation CT scanner.

Intensities of detected x-rays are collected in a data memory 30 as a rotating gantry 24 rotates about the subject. As the data is collected, a reconstruction processor 32 applies a convolution and backprojection algorithm, or other suitable reconstruction technique, to the collected data, forming an image representation. The image representation(s) are stored in an image memory 34. A video processor 36 withdraws selected portions of the image representations and formats them for viewing on a human readable monitor 38 such as a CRT monitor, active matrix monitor, LCD display, or the like.

The first, rotating gantry 24 is disposed within the second, stationary gantry 22. The x-ray source 16 and the detector array 20 are mounted on the rotating gantry 24 along with other associated electronics 44, such as power supplies, data buffers, etc.

The rotating gantry 24 is supported within the stationary gantry 22 by a plurality of tapered roller bearings 46. In the preferred embodiment, there are four sets of two bearings, making eight roller bearings total. Of course, the

number of bearing pairs can be more or less, dependent upon other factors such as the weight of the gantry 24, functional speeds, and the like. Each bearing 46 rotates freely about its own bearing axle, the axle being mechanically fastened to the stationary gantry 22.

With reference to FIGURE 2, the bearings 46 interface with a conical bearing race 50. The race 50 provides surfaces angled with respect to the axis A so that the bearings 46, as shown in FIGURE 2, provide both radial (directions perpendicular to the axis A) support and axial (directions parallel to the axis A) support.

As discussed in the background, the race 50 moves with constant angular velocity, but portions of the race 50 farther from the axis A have higher linear velocities than portions closer to the axis A while the gantry 24 is rotating.

The bearings 46 are tapered into conical shapes to compensate for the linear velocity deviation. When the gantry 24 rotates, each bearing 46 in contact with the gantry 24 also rotates. Being conical in shape, the bearings each have a wide or larger diameter end and a narrow or smaller diameter end. Like the gantry, the surface at wide end of the bearing moves with a higher linear velocity than the surface at the narrow end. The bearings 46 are shaped with a varying diameter that is proportional to the slope and radial altitude of the race 50 such that there is no slippage between the bearings 46 and the race 50 as they all rotate.

Preferably, the bearings 46 are constructed of a metal core, preferably stainless steel, and coated with a polymeric coating, preferably polyurethane. The coating is preferably more than a surface coat, and more akin to a tire on a tricycle wheel, or the like. The coating is thick enough to provide for smooth cushioning, but thin enough that it stiffly supports the rotating gantry. Although polyurethane is

preferred, other coatings that provide adequate stiffness (preventing axial and radial movement of the gantry 24) while preventing metal-to-metal contact between the race 50 and the bearings 46 are contemplated.

5 With reference to FIGURE 3, one of the bearings is attached to an external drive motor 52 and becomes a drive bearing 54. The drive bearing 54 is coated with a substance that can be different from the other bearings 46 for improved friction with the bearing race 50. Such a substance may be a
10 hardened rubber or the like.

In order for the conical bearing race 50 and the tapered bearings 46 to be velocity matched, an angle of expansion that describes the growth of the diameter of a bearing 46 along the axle is found. With reference to FIGURE
15 4, the angle ϕ is found to cause velocities V_o and V_i to match on both the race 50 and the bearings 46. First, a ratio of race 50 diameter to bearing diameter is found,

$$R = \frac{D_o}{d_o}$$

20

where D_o is the outer diameter of the race 50 and d_o is the outer diameter of the bearing 46 and R is the ratio of the two measurements. It follows that the angular speed of the bearing ω_t is found by

25

$$\omega_t = \omega_g R$$

30

where ω_g is the angular speed of the gantry in rpm. From geometry of the system it is known that

$$L_c = \frac{D_o - D_i}{2 \sin \alpha}$$

where L_c is the length of the contact surface of the roller bearing 46, and D_i is the inner diameter of the bearing race 50, and α is the angle of elevation of the bearing race 50.

5 Solving for D_i ,

$$D_i = D_o - 2L_c \sin \alpha .$$

10 In order to velocity match the contact surfaces, the velocities V_o and V_i at the extremities of the bearing 46 and race 50 are found to match:

$$V_o = \omega_t \frac{d_o}{2} = \omega_g \frac{D_o}{2} .$$

15 Solving for ω_t ,

$$\omega_t = \omega_g \frac{D_o}{d_o}$$

20 where d_o is the outer diameter of the bearing 46. Similarly,

$$\omega_t = \omega_g \frac{D_i}{d_i}$$

where d_i is the inner diameter of the roller bearing 46. Combining the above two equations, it is found that
25

$$d_i = d_o \frac{D_i}{D_o} .$$

Finally the angle ϕ can be found by:

$$\phi = \arcsin\left(\frac{d_o - d_i}{2L_c}\right).$$

The bearing axial length L_r can be found by:

5
$$L_r = L_c \cos \phi$$

but it is to be understood that the actual length of the roller bearing 46 can vary to be slightly longer or shorter, keeping the same angle ϕ .

10 In an alternate embodiment, and with reference to FIGURE 5, a race 60 is an inverted negative of the race 50. This alternate race 60 still provides both axial and radial support for a gantry 62.

15 In another alternate embodiment, and with reference to FIGURE 6, a race 70 has three faces, tapered roller bearings 72 being adjacent the vertical sides of the race 70. A cylindrical (non-tapered) roller bearing 74 is adjacent the horizontal face of the race 70 since the entire face is equidistant from the axis A and thus does not display a
20 velocity mismatch phenomenon. In this embodiment, the flat bearings 74 provide a gantry 76 with radial support, while the tapered roller bearings 72 provide the gantry 76 with axial support.

Having thus described the preferred embodiments, the invention is now claimed to be:

1. A diagnostic imaging device comprising:
 - a first, stationary gantry (22);
 - a second, rotating gantry (24) having at least two bearing races (50, 60, 70), the second gantry (24) rotating around a subject receiving region (14);
 - a plurality of tapered roller bearings (46, 72) for providing support to the rotating gantry (24) to rotate around an axis of rotation.
2. The diagnostic imaging device as set forth in claim 1, further including:
 - a radiation detecting means (20) for detecting radiation from the subject receiving region;
 - a reconstruction processing means (32) that reconstructs the received radiation into an image representation;
 - a display means (38) that converts the image representation into a human readable image.
3. The diagnostic imaging device as set forth in claim 2, further including:
 - an x-ray producing means (16) mounted on the rotating gantry (24) to transmit x-rays through the subject receiving region (14).
4. The diagnostic imaging device as set forth in any one of claims 1, 2, and 3, wherein each tapered roller bearing (46, 72) has a truncated conical surface and rotates about a bearing axis, at a wide end, the conical surface moving with a higher linear velocity than at a narrow end.

5. The diagnostic imaging device as set forth in any one of the preceding claims, wherein:

surfaces of the at least two races (50) move with varying linear velocities in accordance with distance from the rotation axis; and,

surfaces of the tapered roller bearings (46, 72) rotate with varying linear velocities along a longitudinal axis of the bearing (46, 72) at the same angular velocity, the varying linear velocities of the tapered bearing surfaces being proportional to the varying linear velocities of the races (50, 60, 70).

6. The diagnostic imaging device as set forth in any one of the preceding claims, wherein the tapered roller bearings (46, 72) provide at least axial support for the rotating gantry (24).

7. The diagnostic imaging device as set forth in claim 6, wherein the tapered roller bearings (46) provide radial and axial support for the rotating gantry.

8. The diagnostic imaging device as set forth in any one of the preceding claims, further including:

at least one drive means (52) attached to one of the tapered roller bearings (46, 72) for driving the rotating gantry (24).

9. The diagnostic imaging device as set forth in any one of the preceding claims, wherein the at least two races (50) define a conical raceway on the rotating gantry (24).

10. The diagnostic imaging device as set forth in any one of the preceding claims, wherein each roller bearing (46, 72) includes:

an axle about which the bearing rotates;

a metal core;
a polymeric coating on a contact surface of the bearing.

11. The diagnostic imaging device as set forth in any one of the preceding claims, wherein the roller bearings (46, 72) have a taper angle ϕ defined by:

$$\phi = \arcsin\left(\frac{d_o - d_i}{2L_c}\right)$$

where d_o is a large end diameter of the bearing, d_i is a small end diameter of the bearing, and L_c is a length measured along a surface of the bearing between the large and small ends.

12. A method of diagnostic imaging comprising:
supporting a rotating gantry (24), which surrounds a subject receiving region (14) with a plurality of tapered roller bearings (46, 72) attached to a stationary gantry (22);
rotating the gantry (24) concurrently on the roller bearings (46, 72), bearing races (50, 60, 70) of the gantry (24) contacting surfaces of the bearings.

13. The method as set forth in claim 12, further including:

gathering data representative of radiation received from the subject receiving region (14);

reconstructing the data into an electronic image representation;

converting the image representation into a human readable display.

14. The method as set forth in claim 13, further including:

transmitting x-rays from a source (16) mounted on the rotating gantry (24) through the subject receiving region (14), the gathering step including detecting the x-rays that traversed the subject receiving region (14).

15. The method as set forth in any one of claims 12, 13, and 14, further including:

rotating at least two bearing races (50, 60) with varying linear velocities in accordance with distance from the rotation axis; and,

rotating surfaces of the tapered roller bearings (46, 72) with varying linear velocities along a longitudinal axis of the bearing (46, 72) at the same angular velocity, the varying linear velocities being proportional to the varying linear velocities of the races (50, 60, 70).

16. The method as set forth in any one of claims 12-15, further including:

providing at least axial support to the rotating gantry (24) with the tapered roller bearings (46, 72).

17. The method as set forth in claim 16, further including:

providing radial and axial support for the rotating gantry (24) with the bearings (46, 72) in a two bearing race (50, 60) system.

18. The method as set forth in any one of claims 12-17, further including:

defining a taper angle ϕ of the roller bearings (46, 72) by the relationship:

$$\phi = \arcsin\left(\frac{d_o - d_i}{2L_c}\right)$$

where d_o is a larger end diameter of the bearing, d_i is a smaller end diameter of the bearing, and L_c is a length between the larger and smaller ends measured along a surface of the bearing.

19. The method as set forth in one of claims 12, further including:

covering a contact surface of the roller bearings (46, 72) with a polyurethane coating.

20. A roller bearing (46, 72) for use in conjunction with a computed tomography scanner, the roller bearing comprising:

an axle about which the bearing rotates

a tapered, conical body having a trapezoidal cross-section, the tapered surface of the body being a contact surface that interfaces a bearing race of a rotating gantry of the computed tomography scanner, a taper angle ϕ of the bearing being defined by:

$$\phi = \arcsin\left(\frac{d_o - d_i}{2L_c}\right)$$

where d_o is a larger end diameter of the bearing, d_i is a smaller end diameter of the bearing, and L_c is a length between the larger and smaller ends measured along a surface of the bearing;

a polymeric coating on the contact surface of the bearing body.

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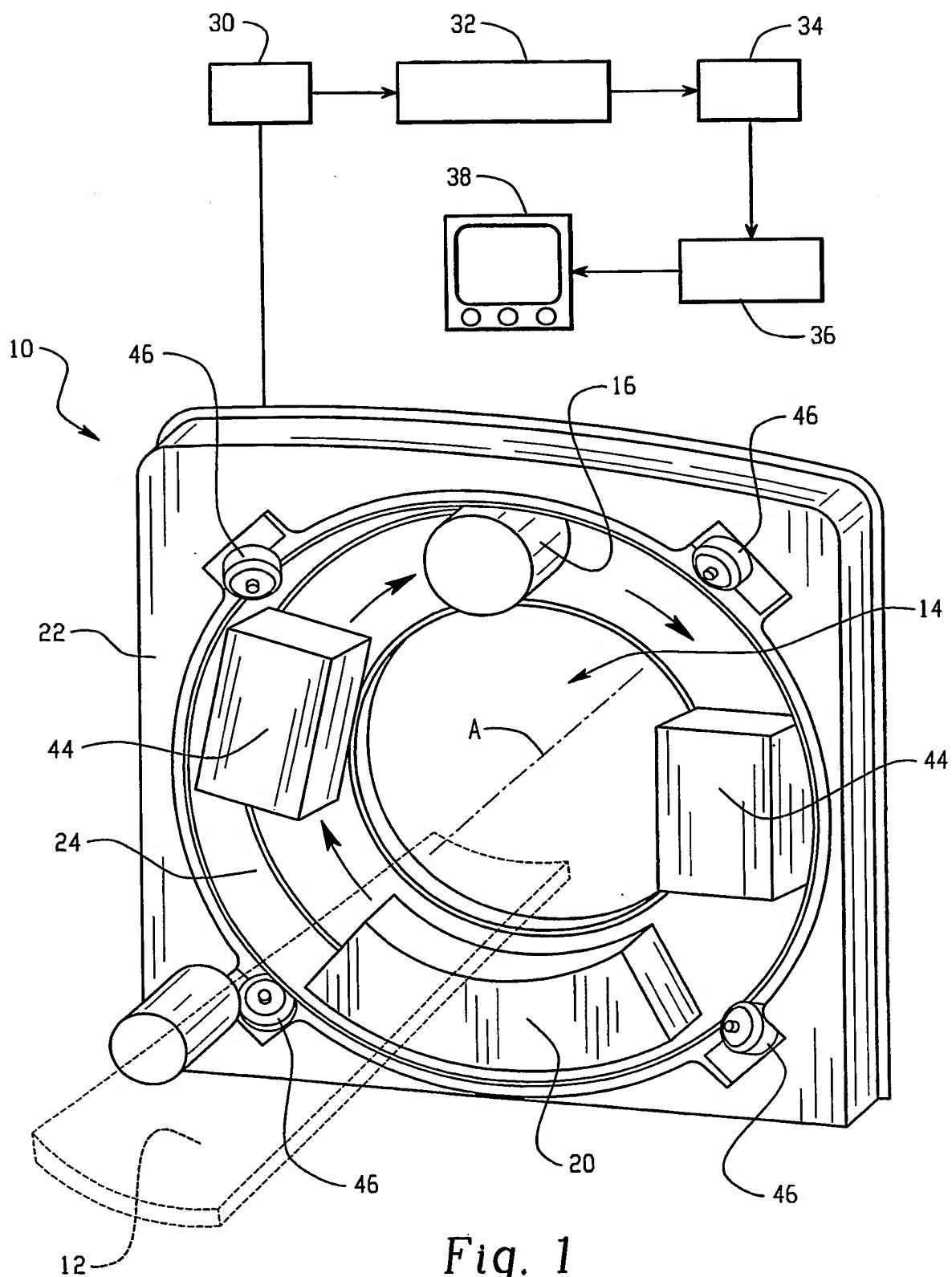


Fig. 1

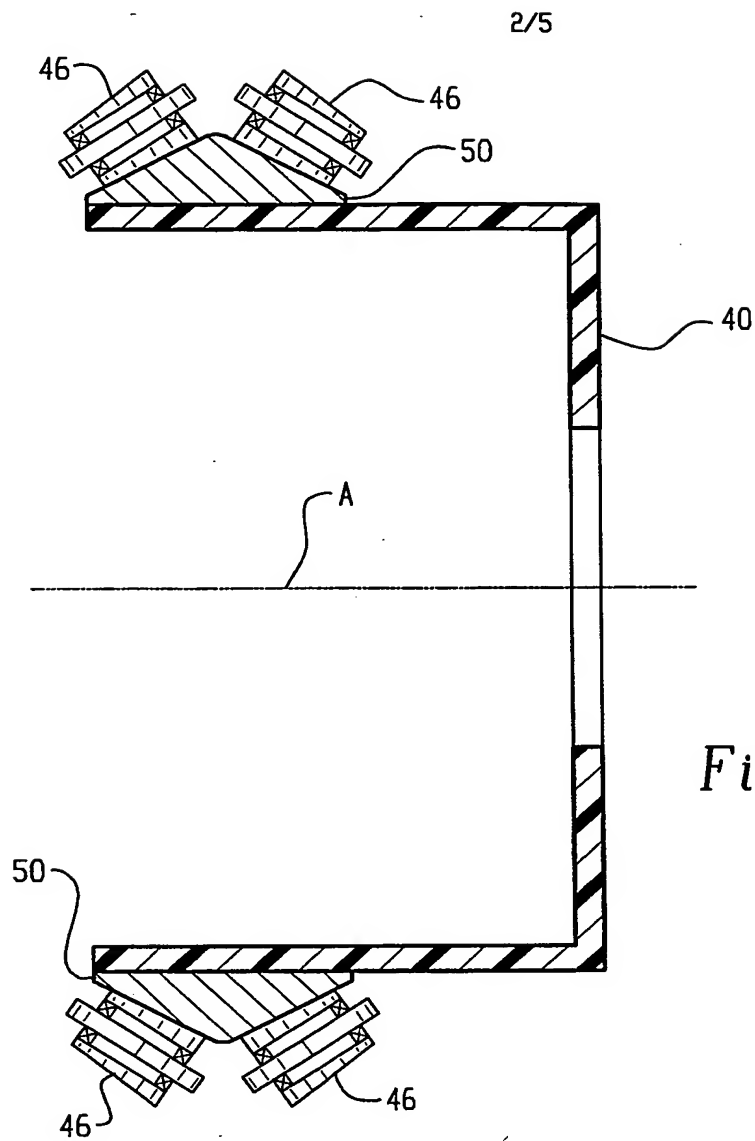


Fig. 2

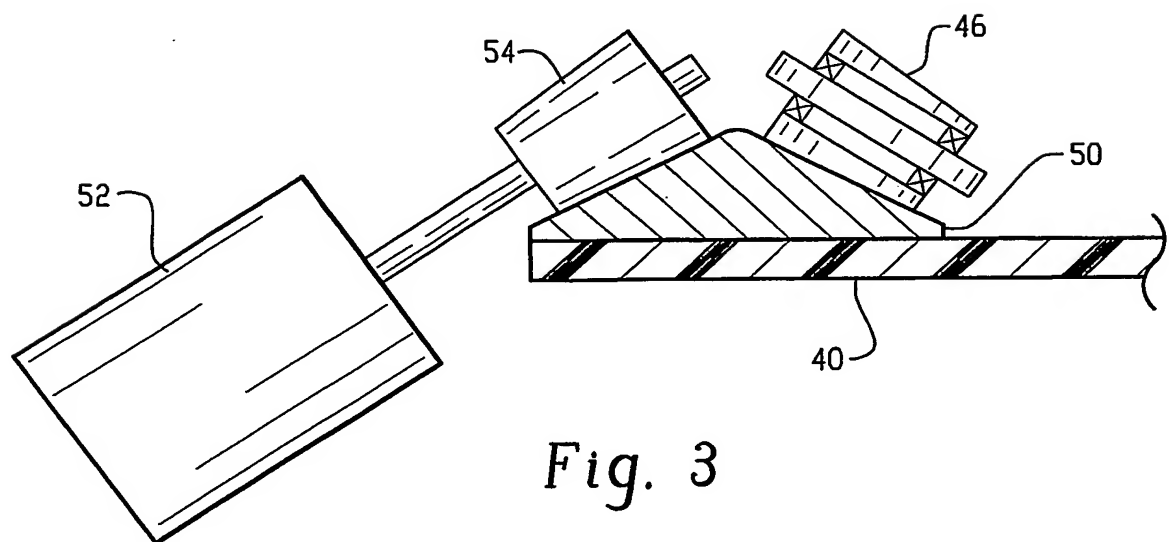


Fig. 3

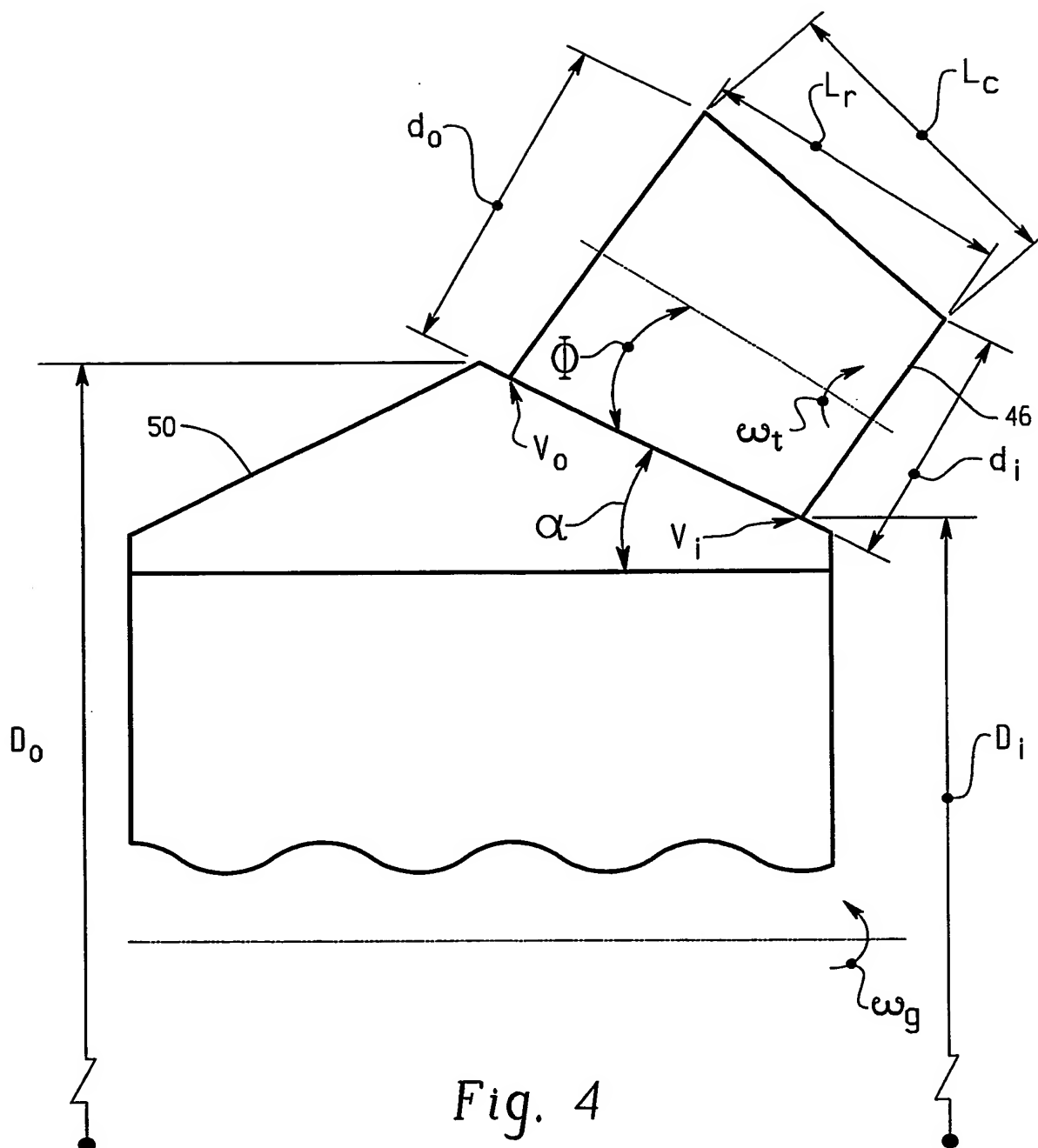


Fig. 4

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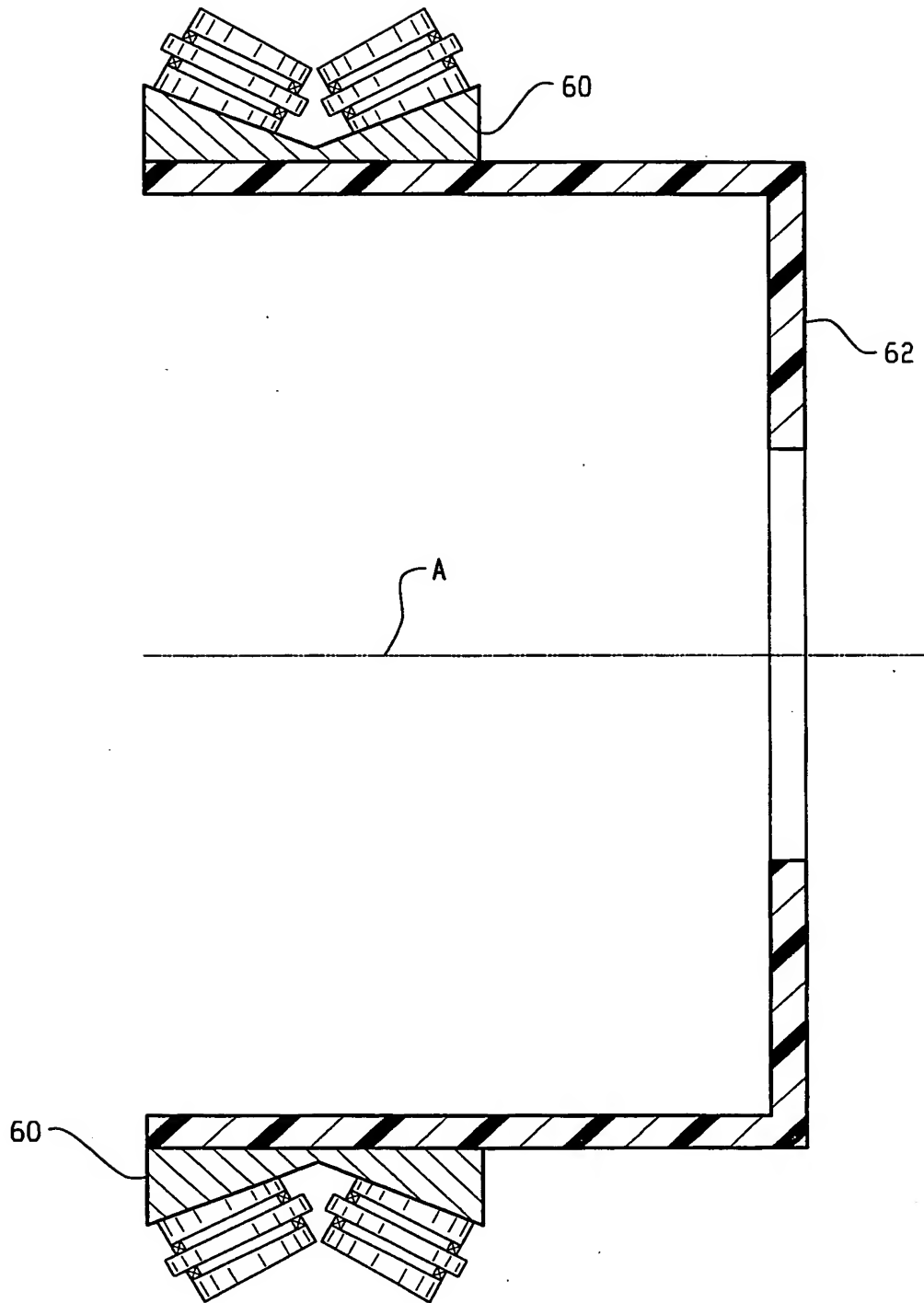


Fig. 5

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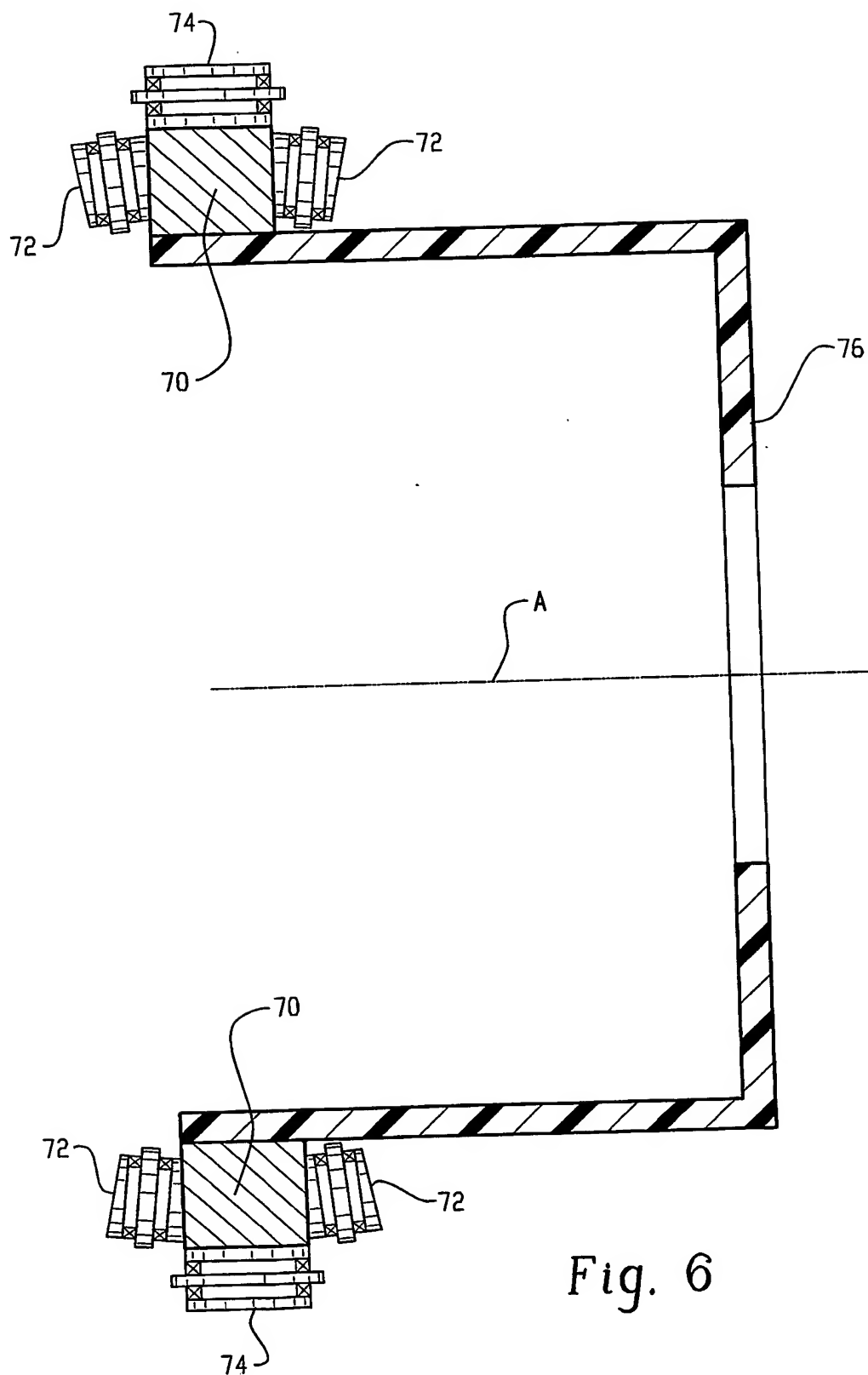


Fig. 6

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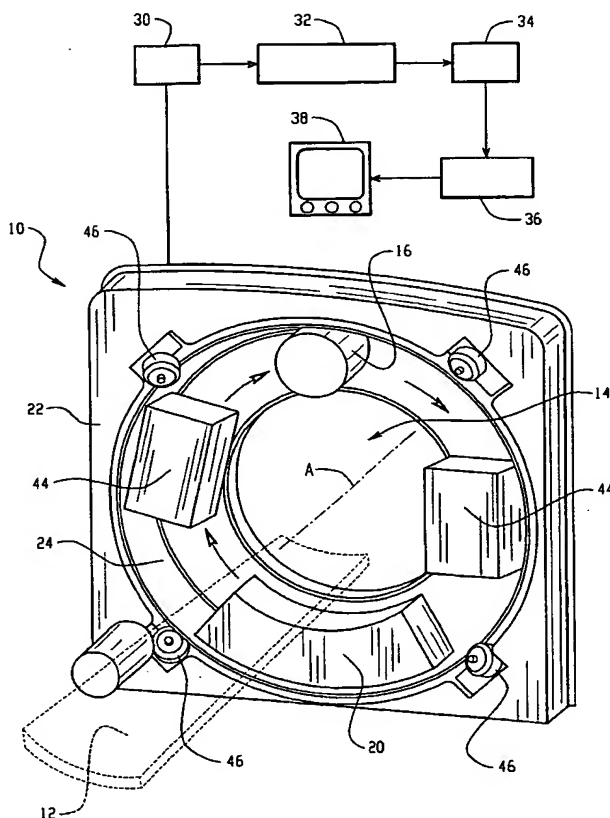
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- (71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).
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- (72) Inventors: BRUNETT, William, C.; 595 Miner Road, Cleveland, OH 44143 (US). SHARPLESS, Ronald, B.; 595 Miner Road, Cleveland, OH 44143 (US).
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- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,

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INTERNATIONAL SEARCH REPORT

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PCT/IB 03/03692

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 A61B6/03 F16C19/36		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 7 A61B F16C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EP0-Internal, INSPEC		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 784 428 A (SCHMIDT MARTIN) 21 July 1998 (1998-07-21) column 1, line 45 - column 2, line 44	1-3,12, 16,17
A	US 6 337 894 B1 (DUFFY MICHAEL J ET AL) 8 January 2002 (2002-01-08) column 3, line 11 - column 4, line 9	1-3,12, 16,17
A	US 4 651 007 A (PERUSEK ALLAN J ET AL) 17 March 1987 (1987-03-17) column 5, line 5 - column 6, line 41	1,12
A	US 6 022 325 A (ASSA MENACHEM ET AL) 8 February 2000 (2000-02-08) column 12, line 1 - line 13	1,12
<input type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "Z" document member of the same patent family		
Date of the actual completion of the international search 24 November 2003		Date of mailing of the international search report 12 03 2004
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer Manschot, J

Form PCT/ISA/210 (second sheet) (July 1992).

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 03/03692

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-19

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-19

Diagnostic imaging device

2. claim: 20

Roller bearing

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International Application No
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